

Rills and ephemeral gullies development during an extreme rainfall period in agricultural lands (NW Spain)

Taboada-Castro, M.M.¹ – Rodríguez-Blanco, M.L. – Diéguez-Villar, A. – Taboada-Castro, M.T.

¹Facultad de Ciencias, Universidad de A Coruña. A Zapateira. 15071 A Coruña. Spain. Tel.: +34 981167000, Fax: +34 981167065; E-mail: teresat@udc.es

1. Abstract

This paper is focused on the erosion systems in both, a small agricultural catchment and a hillslope in the NW Spain, giving a special attention to the characteristics of rill and ephemeral gully developed. The erosion measures were carried out during an extremely wet season, in which rainfall intensities exceeded 10 mm/h. Moreover, the return period of the most intense event was of about 125 years. As a consequence, the frequency and severity of overland flow was much higher than in previous years. The soils show a silt-loam texture being susceptible to the crusting when they are tilled. Eroded soil volumes from rills and gullies were calculated for the two case studies, i.e. hillslope and catchment. The soil volume removed for gully bottom valley formation was 53.87 m³. In hillslope the soil losses were very high, reaching 39.98 m³/ha after 664.7 mm of rainfall and 41.80 m³/ha, then 1055.8 mm of rainfall. The main factors controlling concentrated erosion evolution were discussed. Both case was relate with rainfall and surface soil condition.

2. Introduction

Soil erosion has been recognized as the major cause of land degradation worldwide. Recent studies (de Vente et al. 2005; Valentin et al., 2005) indicated that gully erosion is often the main source of sediment. In extreme events, erosion patterns may change from sheet to rill and gully erosion and soil losses may largely override soil losses by more normal surface runoff events. Large differences may occur due to soil type, topography and agricultural management. A dramatic erosion event may have a long recurrence interval, but the results may last for years and can even be permanent.

In temperate humid environments, the soil loss by erosion concentrate, in rills and gullies, is most important than the sheet erosion (Casalí et al., 1999; Poesen et al., 2003; Vanwalleghe et al., 2005; de Santisteban et al., 2006). Concentrated flow erosion occurs frequently in areas of Western Europe devoted to intensive agriculture (Boardman, 1990; Ludwig et al., 1996) as well as in other European regions with different agricultural systems and soil types (Oygarden, 2003). Vandaele and Poesen (1995) found that the mean, annual ephemeral gully erosion equals 70-75% of the mean annual rill erosion and is associated with extreme runoff events. Auzet et al. (1993) found that ephemeral gully erosion during winter equals about 80% of soil loss due to rill erosion. These results indicate that gully erosion may be the dominant source of sediment transport in cultivated catchments.

In the Northwestern Spain, the few studies of erosion by flow concentrate were conducted at hillslopes and small agricultural catchment with silt and silt-loam texture soils, i.e. very prone to crusting (Taboada and Valcárcel, 1999; Valcárcel et al., 2003). These researches was shown that in cultivate soil, erosion is produce in fields without cultivate in winter or that are sowed with winter cereal, and in field with summer crop that do not offer mulching for protection erosion soil in spring and summer.

The period autumn–winter 2000/01 has been one more humid in NW Spain. This determined that many fields in beginning of autumn remained in fallow land and other were sowed later. This caused most vulnerability to soil erosion and originated ephemeral gullies. This study presents the results of a field survey in both, a hillslope and a small agricultural catchment, where rills and ephemeral gullies were measured after this extreme rainfall period.

2. Material and methods

The survey was conducted in A Coruña Province (NW Spain), on a hillslope (5.7 ha) and a small catchment about 30 ha, both with agricultural use. Morphological characteristics of the catchment and hillslope are given in table 1. The parent material is basic schist that belongs to the “Ordenes Complex” (Martínez et al., 1984). The soil texture is silt-loam, being susceptible to the crusting when they are tilled (Taboada et al., 2006).

The mean slope in the hillslope is 7.13%. In 2000 autumn, 3.2 ha area was tilled, a small part was sown with grassland and the rest was fallow. The sowing in the grassland and tillage in the fallow were between 5 and

10 October. At the end of October concentrated erosion was observed. The slope in the catchment ranges between 3.3-13%. During the study period, the land use in the highest part was grassland and the lowest areas were tilled in the beginning of autumn. Part of the tilled surface was sown with grassland the day 24 October 2000 and the rest were in fallow. In the lowest part of the valley, a gully was formed. It is about a typical gully to the bottom valley (Morgan, 2005), that may be considerate like a broad and few deep rill. At the finish rain period (2001 February 10) besides the gully was distinguish a system rills in fallow land.

Table 1 Morphological characteristics of study units

	Area (ha)	Slope (%)	Crop and tillage
Catchment	30	<3.3-13	Grassland in the highest part and the lowest grassland freshly sowed and fallow
Hillslope	5.7	7.17	Grassland freshly sowed in a part and fallow in other

Between 1 October 2000 and 15 February 2001 an unusually high amount of intense storms (> 10 mm/h) were recorded. The accumulated rainfall was 1063.3 mm.

Volumes of soil lost by erosion were assessed by measuring lengths and representative cross-sections of rills and gullies present. The soil volume was converted into weight by multiplying with a mean bulk density of 1500 kg/m^3 . Rills and ephemeral gullies in a hillslope were measured in two dates: 2000/10/16 and 2001/2/21. In the catchment they were measured 2001/2/16.

3. Results and discussion

In the catchment soil surface evolution was very rapid. It was possible distinguish between the soil loss belong to gully of bottom valley and rill (Table 2). The rainfall recorded between 1st October 2000 and 16th February 2001 was 1063.3 mm. Soil lost during this extremely rainy period reached important values. The soil volume removed for gully bottom valley formation was 53.87 m^3 . Soil losses in rills situated in the fallow land was 8.47 m^3 . The maximum size gully was 317 m of long and 5.59 m width. More broad zone coincide with ephemeral channel of field with fallow land. Their deep maximum was 39.5 cm and only 3 sections, over 65 measures exceeded the 25 cm to deep, which indicate that the soil losses were limited to the superficial horizon. The ephemeral gully formation is indicative of accelerated erosion, and therefore unstable landscape. Its presence may be sign that soil degradation for water erosion has entered in critical phase that may be irreversible (Morgan, 2005).

Table 2 Accumulated rainfall and soil loss (volumes) measures in rills and gullies in the catchment during the period 1 October 2000-16 February 2001

Period	Accumulated rainfall (mm)	Rills (m^3)	Gully (m^3)
1/October/2000-16/February/2001	1063.3	8.47	53.87

During observation made in study period, was possible verify that runoff come from so much of the grassland located in higher part of the catchment as the grassland freshly sowed. In the latter, the water from their hillslope was channelled for wheel track to favour slope until to concentrate on natural drainage line. Also water is accumulated in fallow land after soil surface crusting. In addition, the catchment received external inputs of water from ditch, that discharging into its top. In the gully formation probably contributed, the soil saturation by rainfall of low intensity.

The table 3 shows the accumulated rainfall values and soil loss erosion in the hillslope obtained during 2 measured campaigns. In this hillslope at the end of October, it formed network rills, development which originated ephemeral gullies along topographic and agricultural features. The soil losses were very high, reaching $39.98 \text{ m}^3/\text{ha}$ at the end of the first measurement period after 664.7 mm of rainfall and $41.80 \text{ m}^3/\text{ha}$ in February 2001, then 1055.8 mm of rainfall.

In table 3 can be observed that major part of losses is place from October initial to mid – December 2000. It is also noted that erosion magnitude is much higher on the surface horizon that in the deep horizons. The contribution of B and C horizons to soil losses supposed 4.63% and 6.97% of the registered on the tillage horizon. The concentrations of the deep horizons tends to increase in terms of rainfall, as its moves the winter.

Table 3 Accumulated rainfall and total soil loss (volumen and weight) measures in the hillslope during the period autumn-winter 2000-01.

Date	16/December/2000	21/February/2001
Accumulated rainfall (mm)	664.7	1055.8
Surface horizon (m ³ /ha)	38.21	41.80
Surface horizon (t/ha)	57.31	62.7
Deep horizon (m ³ /ha)	1.77	2.91
Deep horizon (kg/ha)	2.65	4.36

4. Conclusions

Our field assessments show high erosion rates due to rill and ephemeral gully. The critical period for gully and rill formation occurs when soil is unprotected by vegetation and crusting. There was the formation of ephemeral gullies produced as a result of high rainfall and favoured by agricultural practices carried out at that time. Gully erosion is a cause of land degradation affecting soils prone to crusting. Under extremely rainfall events gully erosion is the main source of sediment at the catchment scale. In hillslope of erosion concentrate intensity was so magnitude that soil losses of deep horizon was caused. Concentrated erosion may transport large amounts of sediment to streams, unless buffer zones between the eroded surface and the permanent watercourses were present. It is therefore important to obtain field data about rill and gully development during exceptional events.

Acknowledgements.

This work was supported by Xunta of Galicia (Spain) under projects XUGA10309B96 and PGIDIT05RAG10303PR.

5. References

- Auzet, A.V., Boiffin, J., Papy, F., Ludwig, B., Maucorps, J., 1993. Rill erosion as a function of the characteristics of cultivated catchments in the north of France. *Catena*, 20: 41-62.
- Boiffin, J., 1984. La dégradation structurale des couches superficielles du sol sous l'action des pluies. Thèse docteur-ingénieur. Paris INA-PG.
- Boardman, J., 1990. Soil erosion in the South Downs: a review. In: Boardman, J., Foster, D.A., Dearing, J.A. (Editors.), *Soil Erosion on Agricultural Land*. Wiley, Chichester, UK, pp. 87-105.
- Casalí, J., López, J.J., Giráldez, J.V., 1999. Ephemeral gully erosion in southern Navarra, Spain. *Catena*, 36: 65-84.
- De Santisteban, L. M., Casalí, J., López, J. J., 2006. Assessing soil erosion rates in cultivated areas of Navarre (Spain). *Earth Surf. Process. Landforms*, 31: 487-506.
- De Vente, J., Poesen, J., Verstraeten, G., 2005. The application of semi-quantitative methods and reservoir sedimentation rates for the prediction of basin sediment yield in Spain. *J. of Hydrol.*, 305: 63-86.
- Ludwig, B., Auzet, A.V., Boiffin, J., Papy, F., King, D., Chadoeuf, J., 1996. Etats de surface, structure hydrographique et erosion en rigole de bassins versants cultivés du Nord de la France. *Et. Gest. Sols*, 3 (1): 53-70.
- Martínez, J. R., Klein, E., De Pablo, J. G., González, F., 1984. El Complejo de Ordenes: Subdivisión, descripción y discusión sobre su origen. *Cuad. Lab. Xeol. Laxe*, 7: 139-210.
- Morgan, R.P.C., 2005. *Soil Erosion and Conservation*. Blackwells. pp. 314.
- Oygarden, L., 2003. Rills and gully development during an extreme winter runoff event in Norway. *Catena*, 50: 217-242.
- Poesen J, Nachtergaele J, Verstraeten G, Valentin C., 2003. Gully erosion and environmental change: importance and research needs. *Catena*, 50: 91-133.
- Valcárcel M, Taboada M.T., Dafonte J., 2003. Ephemeral gully erosion in northwestern Spain. *Catena*, 50: 199-216.
- Valentin, C., Poesen, J., Yong Li., 2005. Gully erosion: Impacts, factors and control. *Catena*, 63: 132-153.
- Vandaele, K., Poesen, J., 1995. Spatial and temporal patterns of soil erosion rates in an agricultural catchment, central Belgium. *Catena*, 25: 213– 226.

- Vanwalleghem, T., Poesen, J., Nachtergaele, J., Verstraeten, G., 2005. Characteristics, controlling factors and importance of deep gullies under cropland on loess-derived soils. *Geomorphology*, 69: 76– 91.
- Taboada, M.M., Valcárcel, M., 1999. Condiciones de formación de la escorrentía en suelos de cultivo. In: Taboada Castro, M.T. (Editor.), *Avances Sobre el Estudio de la Erosión Hídrica*. Universidad de A Coruña. A Coruña. España, 52pp. 69-99.
- Taboada M.M., Diéguez A., Taboada M.T., 2006. Crusting of agricultural soils under different soil tillage operations. *Proceedings of the International Symposium Agro Environ 2006*. pp. 355-363.